The application of photonic lanterns in free space optical communications

Sarah A. Tedder
NASA Glenn Research Center, 21000 Brookpark Road, Cleveland, OH, USA 44135

ABSTRACT

Photonic lanterns offer an efficient solution to transition distorted light from free space into small aperture or single-mode waveguide devices. As a result, photonic lanterns can be useful for free space optical communications, where light is transmitted across a channel with varying atmospheric conditions. This paper will give an overview of studies using photonic lanterns in photon counting optical communication receivers where the detectors are small in aperture and fiber coupled. This paper will also survey other potential uses of photonic lanterns in coherent optical communication receivers or as wavefront sensors in adaptive optical systems.

Keywords: Optical communications, Photonic lanterns

1. INTRODUCTION

Photonic lanterns were originally invented to increase the amount of light delivered to multiple single-mode fiber Bragg gratings for astronomical applications[1-2]. Since then, photonic lanterns have been proposed to be used in ground receivers of space to ground optical communications, due to the similar need to efficiently deliver atmospherically distorted light into small-core or a single mode fiber [3-8]. Photonic lanterns are under investigation to benefit two optical communications waveforms: pulse position modulation and coherent. This paper provides an overview of the results of those investigative efforts.

2. PHOTONIC LANTERNS FOR PULSE POSITION MODULATION

Pulse position modulation uses a direct detection method where the information is encoded using the timing of light pulses. Pulse position modulation is used for applications where the light level low enough to require photon counting detectors. NASA Glenn is investigating the photonic lantern as a solution to deliver light to commercial-off-the-shelf fiber coupled single photon detectors[8]. The single photon detectors have an area large enough to accommodate efficient coupling (>99%?) with a 20 µm graded index few-mode fiber. This few-mode fiber supports the first 6 linear polarized modes (LP_{01}, LP_{11a}, LP_{11b}, LP_{02}, LP_{21a}, LP_{21b}). At the expected atmospheric conditions, $D/r_0=9$, the energy of light transmitted spacecraft will scatter into more modes than 6, limiting the efficiency of the energy coupled by the FMF to -8 dB as predicted in Ref. [9]. The photonic lantern offers a way to increase the number of modes coupled and therefore the energy efficiency.

Traditional photonic lanterns are fabricated with single mode fibers, for this application the lantern was fabricated with FMFs. This new type of photonic lantern increases the number of modes coupled by the photonic lantern without increasing the number of detectors needed[8]. Figure 1 shows a photograph of the few-mode fiber photonic lantern, packaged and unpackaged.

*Send correspondence to sarah.a.tedder@nasa.gov

Figure 1. A photograph of an unpacking photonic lantern (right), next to a packaged photonic lantern (left).

3. PHOTONIC LANTERNS FOR COHERENT MODULATION

The use of photonic lanterns for coherent modulation receiver systems has been explored through analysis in Refs. [10-12]. Coherent receiver systems require transitioning the light to a single mode fiber to preserve the coherence of the modes sent by the transmitter. A photonic lantern offers a potentially simpler alternative to the commonly used adaptive optic systems as demonstrated in Refs. [13-16]. Not only can photonic lanterns transition light from a multi-mode input into a single mode fiber, they also can provide information about the shape of the wavefront [17]. Using a photonic lantern as a wavefront sensor has the potential to replace the most expensive component of most AO systems. If combined with a photonic integrated circuit to coherently recombine the signals from each leg, PLs enable a smaller solution to coherent receivers [18].

4. SUMMARY

Investigations of photonic lanterns used for optical communications for fiber coupled PPM and coherent receivers demonstrate promise for improved coupling.

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